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# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

DITCHING INVESTIGATION OF A  $\frac{1}{12}$ -SCALE MODEL

OF THE DOUGLAS F3D-2 AIRPLANE

TED NO. NACA DE 381

By Lloyd J. Fisher and William C. Thompson

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## SUMMARY

An investigation of a  $\frac{1}{12}$  - scale dynamically similar model of the Douglas F3D-2 airplane was made in calm water to observe the ditching behavior and to determine the safest procedure for making an emergency water landing. Various conditions of damage were simulated to determine the behavior which probably would occur in a full-scale ditching. The behavior of the model was determined from motion-picture records, time-history acceleration records, and visual observations.

It was concluded that the airplane should be ditched at a medium high attitude of about  $8^{\circ}$  with the landing flaps down  $40^{\circ}$ . In calm water the airplane will probably make a smooth run of about 550 feet and will have a maximum longitudinal deceleration of about 3g. The fuselage bottom will probably be damaged enough to allow the fuselage to fill with water very rapidly.

## INTRODUCTION

A ditching investigation of a model of the Douglas F3D-2 airplane was made to observe the behavior and to determine the safest procedure for making an emergency water landing. This airplane was of particular interest because of the unusual nacelle configuration. Pertinent data for the test were furnished by the Douglas Aircraft Company. A three-view drawing of the airplane is shown in figure 1.

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The ditchings discussed in this paper were made in calm water at the Langley tank no. 2 monorail. The same general type of performance should be obtained in rough-water ditchings made parallel to waves or swells. In rough-water ditchings made perpendicular to waves, more damage and violence of motion may occur, depending on the choice of the ditching site and the portions of the waves contacted.

## APPARATUS AND PROCEDURE

### Description of Model

The  $\frac{1}{12}$  - scale dynamic model of the Douglas F3D-2 airplane shown in figure 2 was used for the investigation. The model was constructed principally of balsa wood and spruce and was covered with silk. Internal ballast was used to obtain scale weight and moments of inertia. The model had a wing span of 4.17 feet and an over-all length of 3.78 feet. The flaps were installed so that they could be fixed in the retracted position or be held in the full-down position at approximately scale strength. A calibrated string was fastened between a flap fitting and a corresponding wing fitting so that water loads greater than the ultimate design load (45 lb/sq ft, full scale) would cause the string to break and thus allow the flaps to rotate to a neutral position. Calibration tests indicated that the string failed within  $\pm 10$  percent of the desired value.

The effect of damage was investigated by removing parts of the model and by making other parts with a crumpled surface to simulate damage which may occur during a ditching. The manufacturer estimated the full-scale strength of the rear fuselage as 4 pounds per square inch. The model was made with a removable rear-fuselage section from fuselage station 371 to 577 and below water line -9.00 (fig. 3) which could be replaced by a crumpled section to simulate damage conditions that may occur during a full-scale ditching. Other strength estimates by the manufacturer were 8 pounds per square inch for the nose section and 6 pounds per square inch for the section where the engine nacelles are located. The nacelle fairings were removable from station 180 to 371 and below water line -21.6 (fig. 3). Based on the strength estimate and previous full-scale ditchings of other airplanes it seems likely that the nacelle fairings would be torn away during a ditching. Past experience has also shown that the jet engines usually remain attached; therefore, simulated engines were rigidly installed in the model when the nacelle fairings were removed. When tests were made with the nacelle fairings installed, the engines were omitted but the openings through the nacelles were about 85 percent restricted.

### Test Methods and Equipment

The model was ditched by catapulting it into the air to permit a free glide onto the water. The model left the launching carriage at scale speed and the desired landing attitude. The control surfaces were set so that the attitude did not change appreciably in flight. The behavior was recorded by a motion-picture camera, from visual observations, and by a time-history accelerometer installed in the pilots' compartment. Both normal and longitudinal components of acceleration were measured with respect to the axes of the airplane. The accelerometer had a natural frequency of 73 cycles per second and was damped to about 65 percent of critical damping. The reading accuracy of the instrument was  $\pm \frac{1}{4}g$ .

### Test Conditions

All values given for these test conditions are full-scale values.

Weight.- A gross weight of 25,000 pounds was simulated in the investigation.

Moments of inertia.- The model was ballasted to obtain the following values of moments of inertia:

Roll, slug-ft <sup>2</sup> . . . . .	18,000
Pitch, slug-ft <sup>2</sup> . . . . .	47,000
Yaw, slug-ft <sup>2</sup> . . . . .	61,000

Center of gravity.- The center of gravity was located at 21.7 percent of the mean aerodynamic chord and 2.7 inches above the fuselage reference line.

Landing attitude.- Three landing attitudes were used in the investigation: 12° (near the lift-curve stall angle), 8° (maximum tail-down static), and 4° (intermediate between maximum tail-down static and three-wheel static). The attitudes were measured with respect to the fuselage reference line.

Flaps.- Tests were made with the flaps up and down 40°.

Landing speed.- The landing speeds as computed from lift curves furnished by the manufacturer are listed in table I. The model was airborne when launched and was within  $\pm 6$  knots of these speeds.

Landing gear.- All tests simulated ditchings with the landing gear retracted.

Model configuration.- The model was tested in the following configurations:

- (a) No damage simulated (fig. 2).
- (b) Nacelle fairings removed, simulated engines installed, and crumpled rear-fuselage section installed (fig. 4).
- (c) Nacelle fairings removed and simulated engines installed (fig. 5).
- (d) Crumpled rear-fuselage section installed (fig. 6).

## RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in table I. The notations used in the table are defined as follows:

Oscillated - The model oscillated about a longitudinal axis.

Porpoised - The model made an undulating motion about a transverse axis with some part always in contact with the water.

Ran smoothly - The model made no apparent oscillation about any axis, gradually settling into the water as the forward velocity decreased.

Skipped - The model made an undulating motion about a transverse axis in which it cleared the water completely.

Trimmed down - The attitude of the model decreased immediately after contact with the water.

Trimmed up - The attitude of the model increased immediately after contact with the water.

Turned sharply - The model made a violent angular motion about a vertical axis.

Figure 7 presents time-history curves of attitude and normal and longitudinal acceleration for the  $12^\circ$  and  $8^\circ$  landing attitudes with nacelle fairings removed and simulated engines and crumpled rear fuselage installed. Sequence photographs of the model ditching are shown in figure 8.

## Effect of Damage

No simulated damage.- The undamaged model at the  $12^\circ$  and  $8^\circ$  landing attitudes with the flaps down generally ran smoothly except for some slight trim changes and oscillations. The maximum longitudinal deceleration was about 2g, the maximum normal acceleration was about  $5\frac{1}{2}$ g, and the total length of landing runs was about 600 feet, full scale (table I). At the  $4^\circ$  attitude the model made one skip of about 500 feet and then on the second contact made a sharp turn resulting in a total length of run of about 550 feet. Ditchings at the  $12^\circ$  and  $8^\circ$  attitudes with the flaps up were rather violent; the model made an initial skip of about 500 feet, one or two short skips of about 15 to 50 feet and then porpoised. The maximum longitudinal deceleration was about 5g, the maximum normal acceleration was about  $10\frac{1}{2}$ g, and the total length of run was about 1200 feet (table I).

Simulated damage.- Ditchings with the nacelle fairings removed and simulated engines and a crumpled rear-fuselage section installed were generally very smooth. At the  $12^\circ$  landing attitude, with the flaps down, the model trimmed down immediately after contact, as can be seen in the attitude curve of figure 7(a), and then made a smooth run of about 500 feet (table I and fig. 8). The maximum longitudinal deceleration was about 3g and the maximum normal acceleration was about 4g (fig. 7(a)). At the  $12^\circ$  attitude with the flaps up, the model trimmed down after contact and made smooth runs of about 550 feet. The maximum longitudinal and normal accelerations were about 5g (table I). The model made very smooth landings at the  $8^\circ$  attitude with the flaps down. (See the attitude curve of fig. 7(b).) At the  $8^\circ$  attitude with the flaps up, the model continued to make smooth runs; however, the longitudinal decelerations were very high, the maximum being about 11g, and the maximum normal acceleration was about  $7\frac{1}{2}$ g. The total length of run was about 600 feet. At the  $4^\circ$  attitude with the flaps down the model skipped and porpoised and made a run of about 650 feet.

When ditchings were made with the flaps down, the nacelle fairings removed, simulated engines installed, and the aft fuselage surface undamaged (fig. 5), the model porpoised slowly throughout a run of about 600 feet. The maximum longitudinal and normal accelerations were each about 6g, approximately twice that of the most fully damaged condition.

Further tests made with a crumpled rear-fuselage section being the only damage simulated (fig. 6) resulted in skipping and porpoising at both the  $12^\circ$  and  $8^\circ$  landing attitudes. The length of run was about 875 feet, the maximum longitudinal deceleration was about 3g, and the maximum normal acceleration was about  $6\frac{1}{2}$ g.

Of the conditions tested, the one with the most damage simulated resulted in the smoothest runs and lowest decelerations. The other two

conditions of simulated damage produced somewhat more violent motions and higher decelerations. Such behavior indicates that a failure of the nacelle fairings and fuselage undersurface is not detrimental as far as behavior is concerned for this particular configuration even though the bottom would be damaged enough to allow the fuselage to fill with water very rapidly.

#### Effect of Attitude

Ditchings at the  $12^\circ$  attitude with the flaps down resulted in higher decelerations than at the  $8^\circ$  attitude with the flaps down. There was little difference in the motions of the model at these two attitudes, except that the ditching runs were somewhat smoother at the  $8^\circ$  attitude. The behavior at the  $4^\circ$  attitude was the most violent and, consequently, ditchings at  $4^\circ$  were the most undesirable. A medium-high attitude of about  $8^\circ$  is, therefore, recommended for a ditching.

#### Effect of Landing Flaps and Speed

The scale-strength flap connections always failed shortly after contact and the flaps rotated to the neutral position. There was no undesirable behavior due to the flaps being down. The higher speeds associated with a flaps-up condition resulted in appreciably greater deceleration than the lower speeds of a flaps-down condition (table I). Thus, it is desirable to have the flaps full down for a ditching so that a minimum landing speed may be obtained.

#### CONCLUSIONS

From the results of the calm-water ditching investigation of a  $\frac{1}{12}$ -scale model of the Douglas F3D-2 airplane, the following conclusions were drawn:

1. The airplane should be ditched at a medium-high attitude of about  $8^\circ$  with the landing flaps down  $40^\circ$ .
2. The airplane will probably make a smooth run of about 550 feet, and the maximum longitudinal deceleration will be about 2g and the maximum normal acceleration about 3g.

3. The fuselage bottom will probably be damaged enough to allow the fuselage to fill with water very rapidly.

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gm



TABLE I

SUMMARY OF RESULTS OF DITCHING INVESTIGATION OF A  $\frac{1}{12}$ -SCALE

MODEL OF THE DOUGLAS F3D-2 AIRPLANE

[Gross weight, 25,000 lb; all values full scale.]

Landing attitude, deg	Flap condition	Landing speed, knots	Maximum longitudinal deceleration, g	Maximum normal acceleration, g	Length of run, ft	Motions of model (1)
No simulated damage						
12	down 40°	101	2	$5\frac{1}{2}$	650	Trimmed up, oscillated
12	up	122	$4\frac{1}{2}$	11	1200	Skipped <sub>500</sub> , skipped <sub>50</sub> , skipped <sub>20</sub> , porpoised
8	down 40°	111	2	4	600	Trimmed up, ran smoothly
8	up	139	5	$10\frac{1}{2}$	1150	Skipped <sub>500</sub> , skipped <sub>40</sub> , skipped <sub>15</sub> , porpoised
4	down 40°	127	---	---	550	Skipped <sub>500</sub> , turned sharply
Nacelle fairings removed, simulated engines installed, and crumpled rear-fuselage section installed						
12	down 40°	101	3	4	500	Trimmed down, ran smoothly
12	up	122	5	$4\frac{1}{2}$	550	Trimmed down, ran smoothly
8	down 40°	111	2	3	550	Ran smoothly
8	up	139	11	$7\frac{1}{2}$	600	Ran smoothly
4	down 40°	127	---	---	650	Skipped, porpoised
Nacelle fairings removed and simulated engines installed						
12	down 40°	101	6	6	550	Porpoised slowly
8	down 40°	111	6	$6\frac{1}{2}$	650	Porpoised slowly
Crumpled rear-fuselage section installed						
12	down 40°	101	3	$6\frac{1}{2}$	850	Skipped, porpoised
8	down 40°	111	2	4	900	Skipped, porpoised

<sup>1</sup>Subscript denotes length of skip in feet.

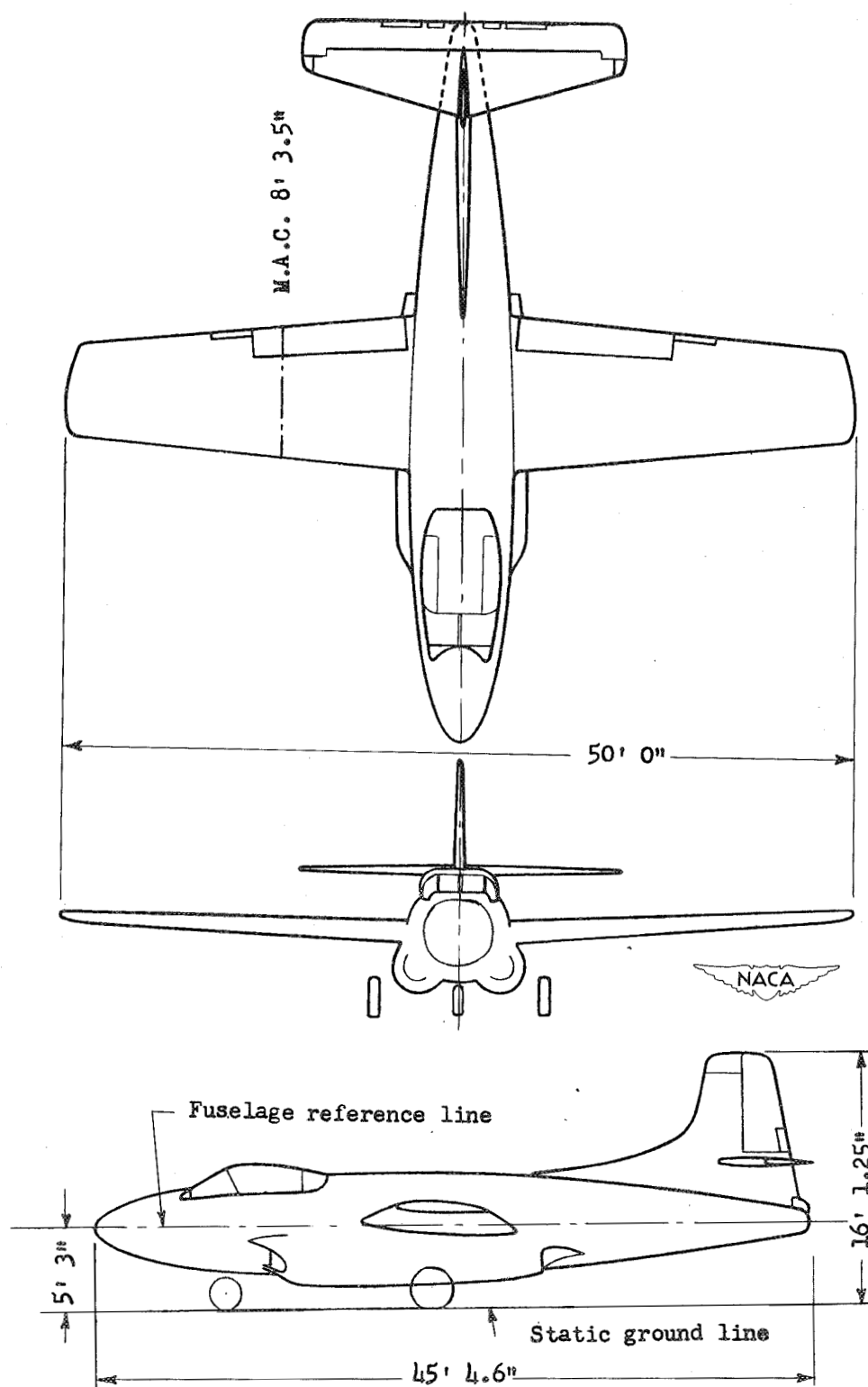
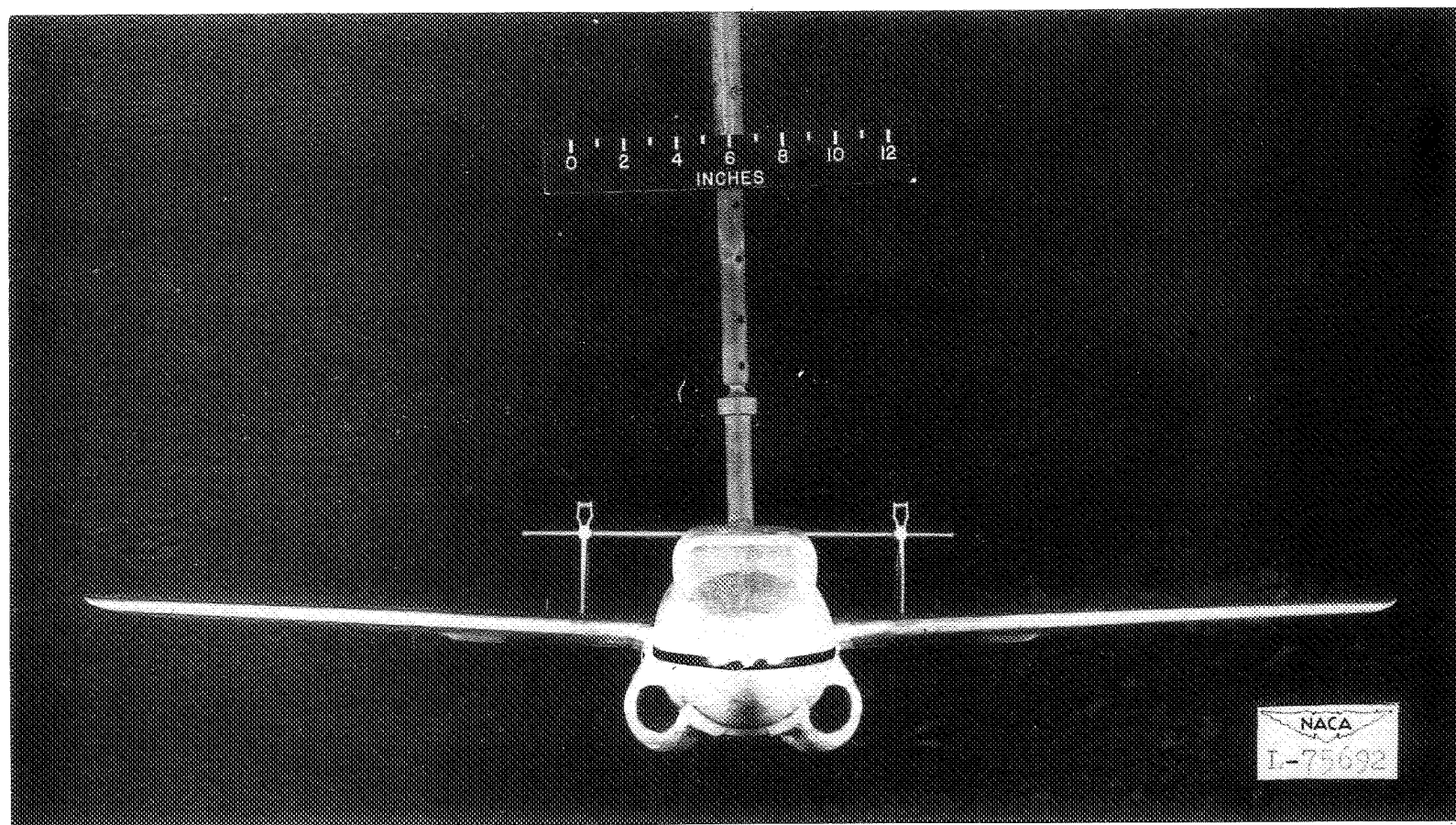
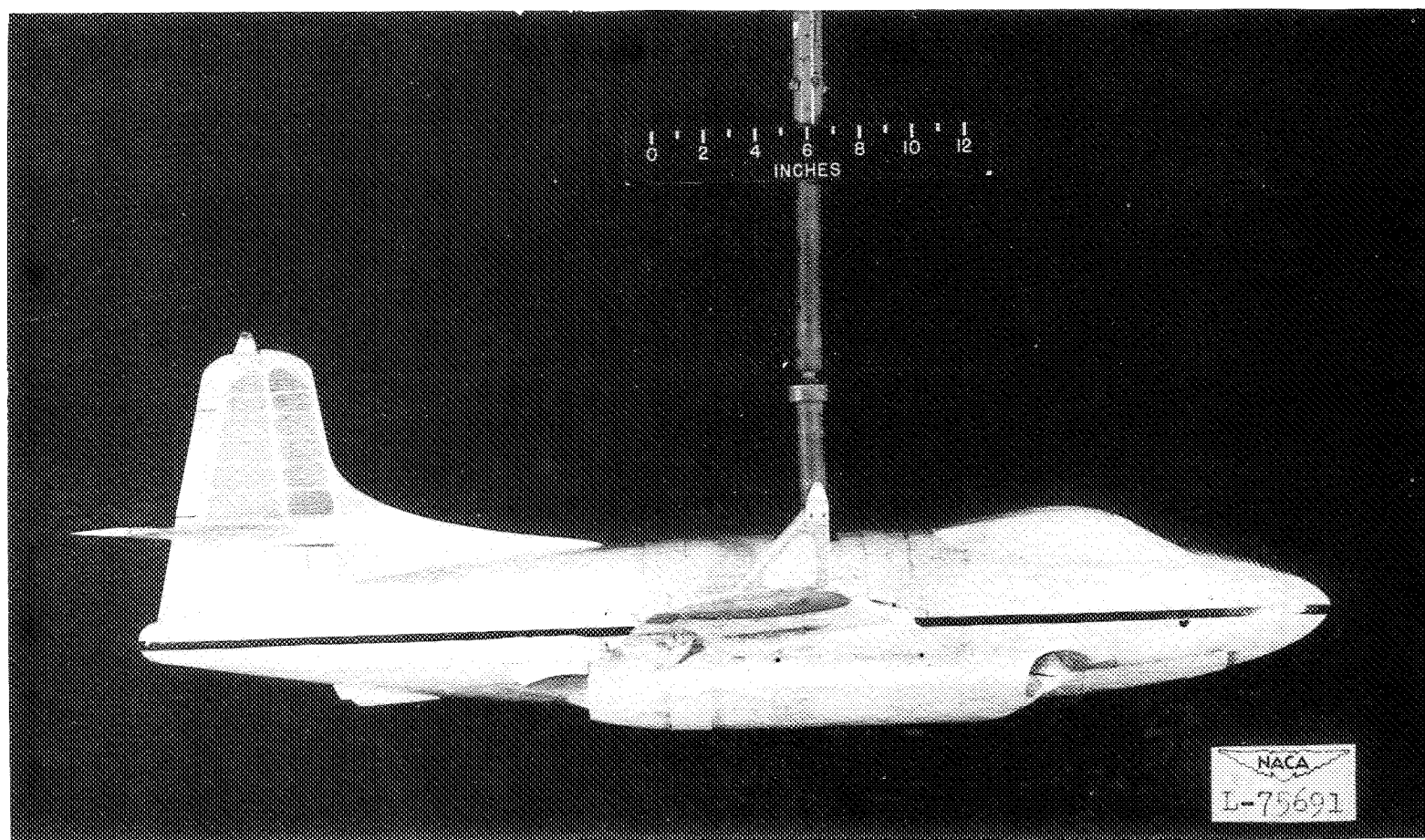


Figure 1.- Three-view drawing of the Douglas F3D-2 airplane.



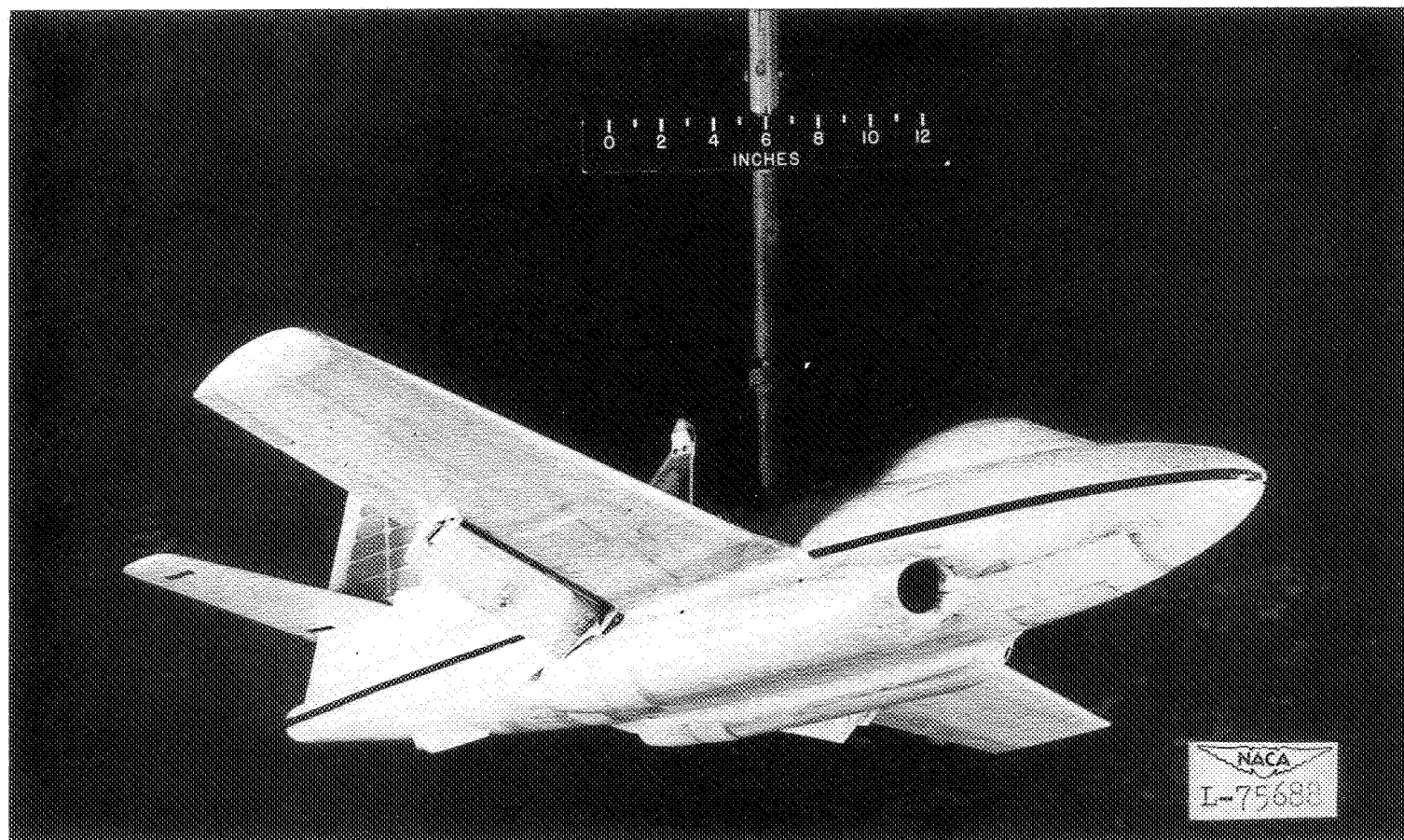
(a) Front view.

Figure 2.- The Douglas F3D-2 ditching model.



(b) Side view.

Figure 2.- Continued.



(c) Three-quarter bottom view.

Figure 2.- Concluded.

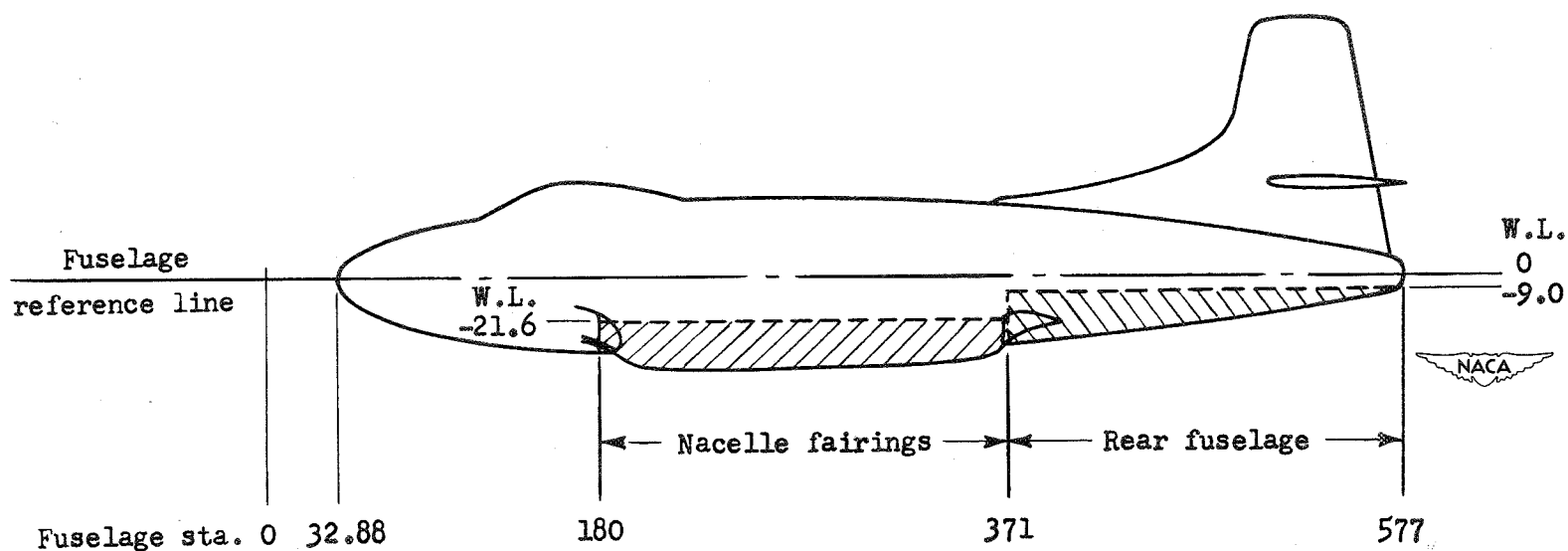


Figure 3.- Location of removable parts.

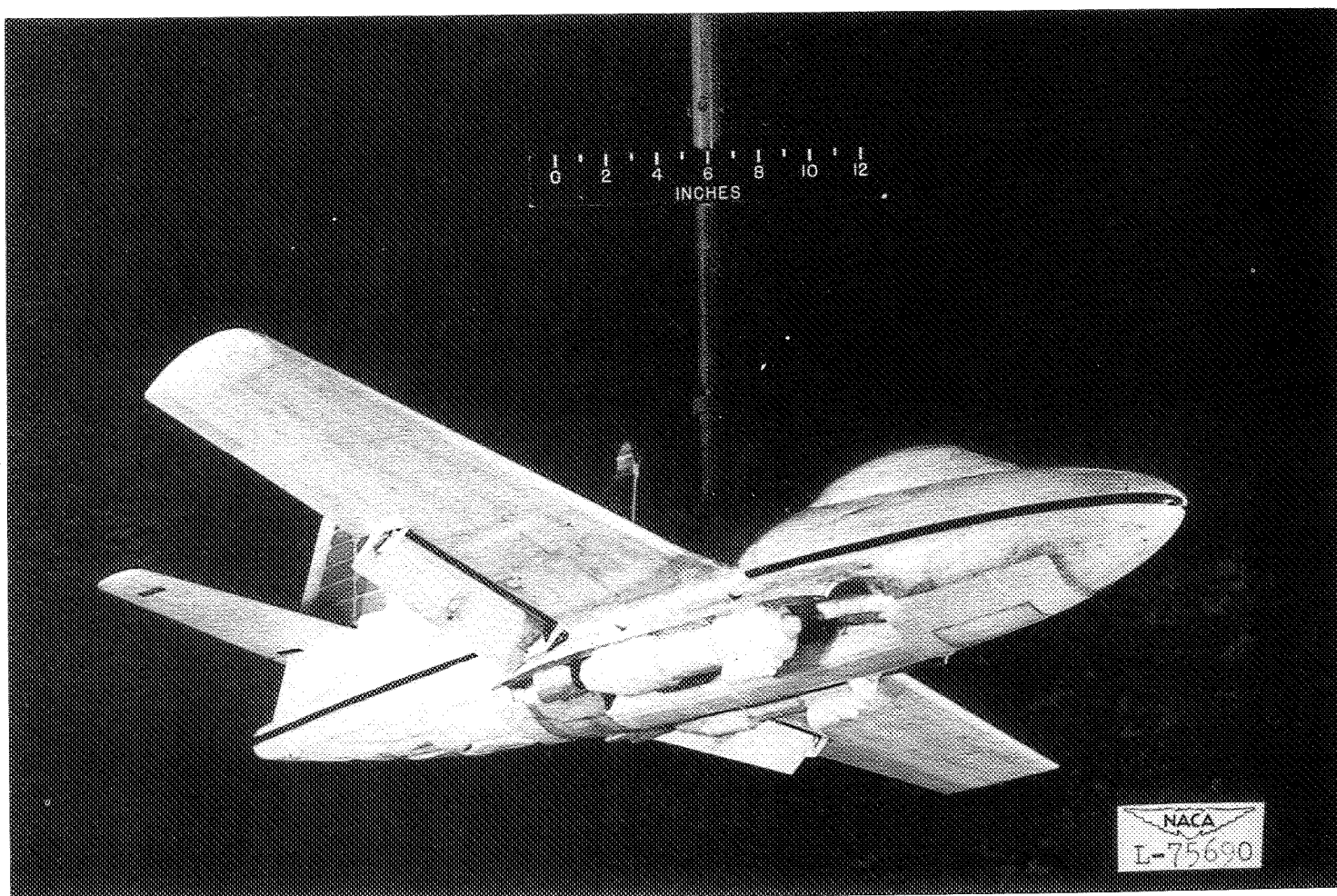


Figure 4.- Model with nacelle fairings removed, simulated engines and crumpled rear fuselage section installed.

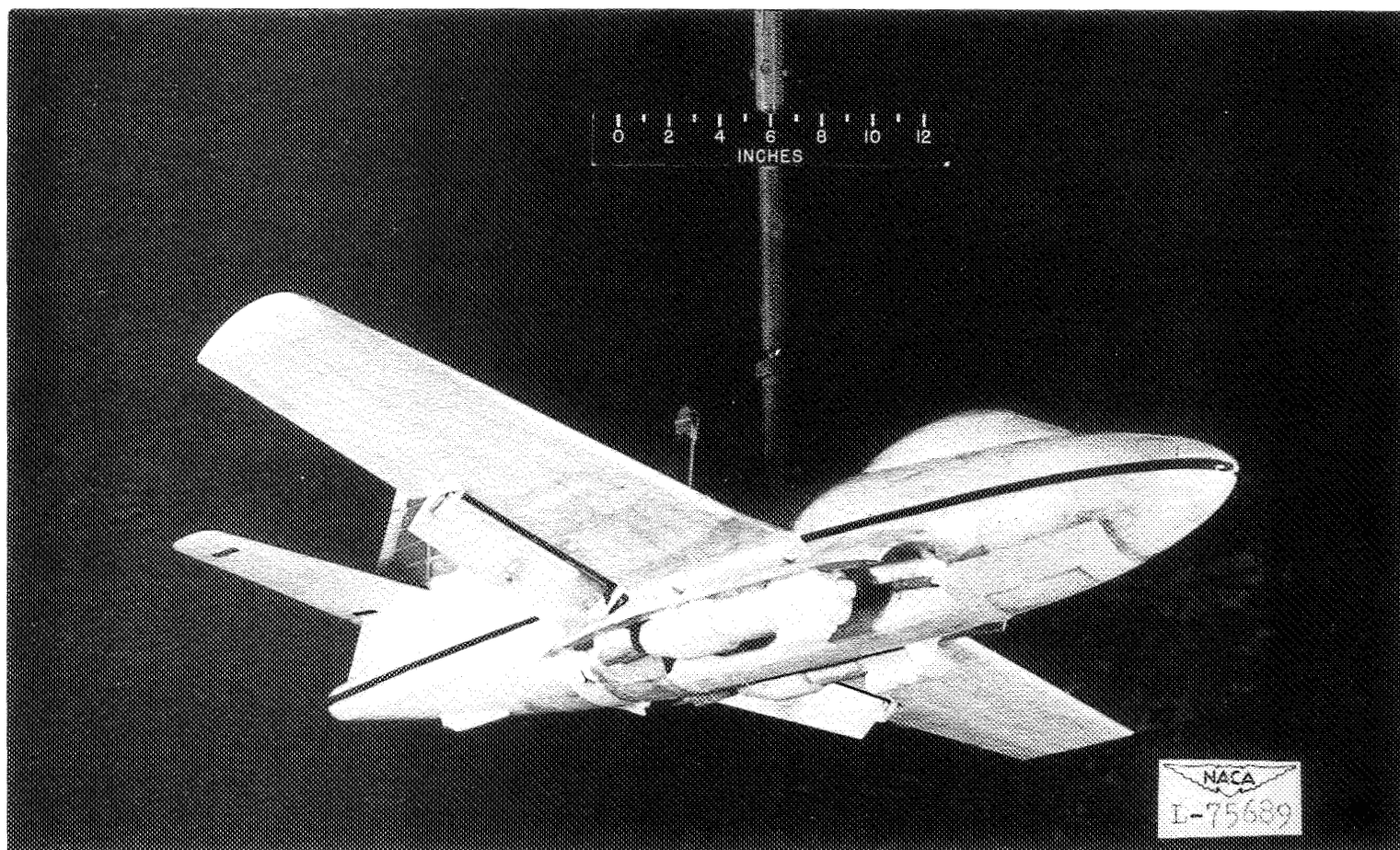


Figure 5.- Model with nacelle fairings removed and simulated engines installed.



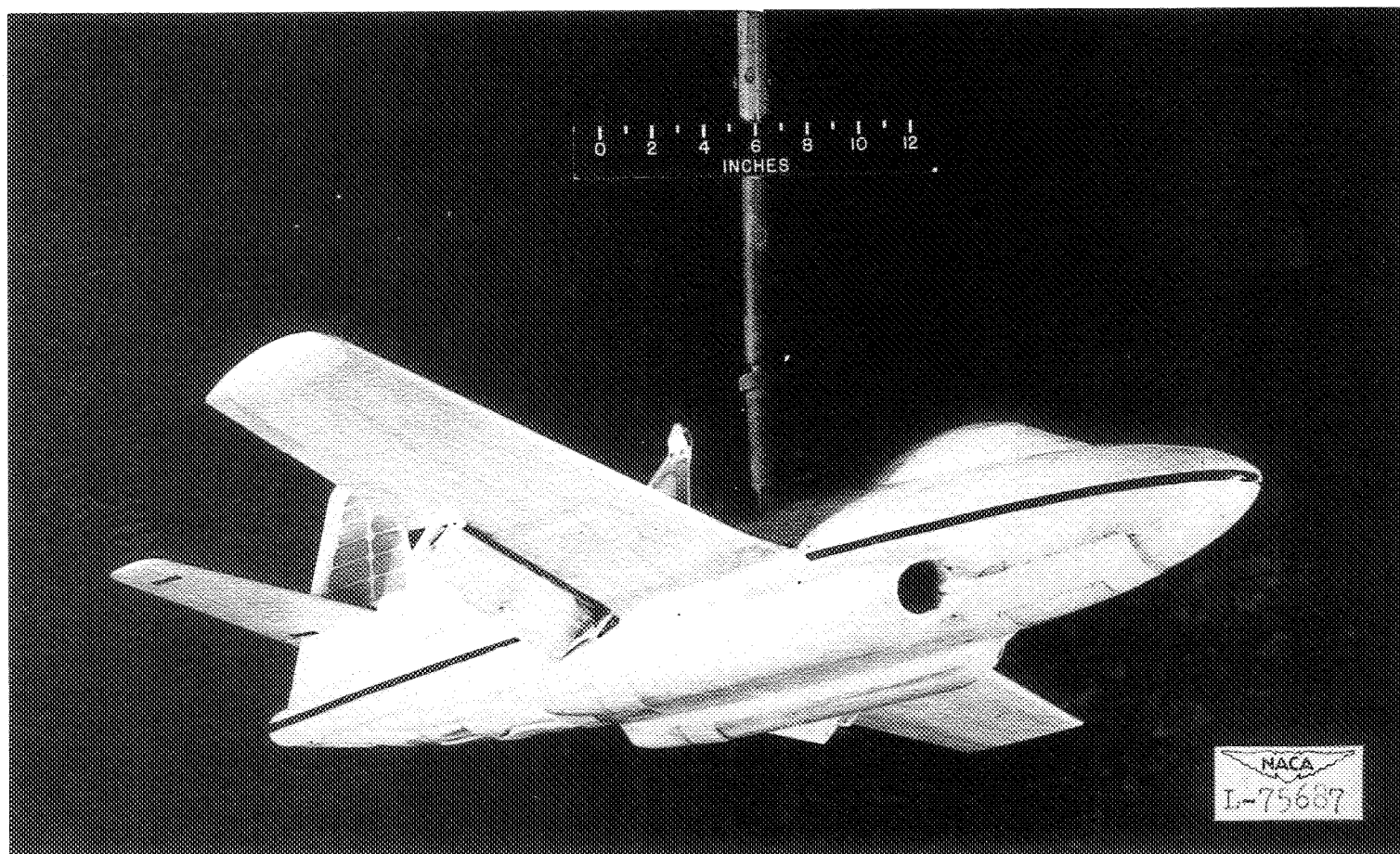
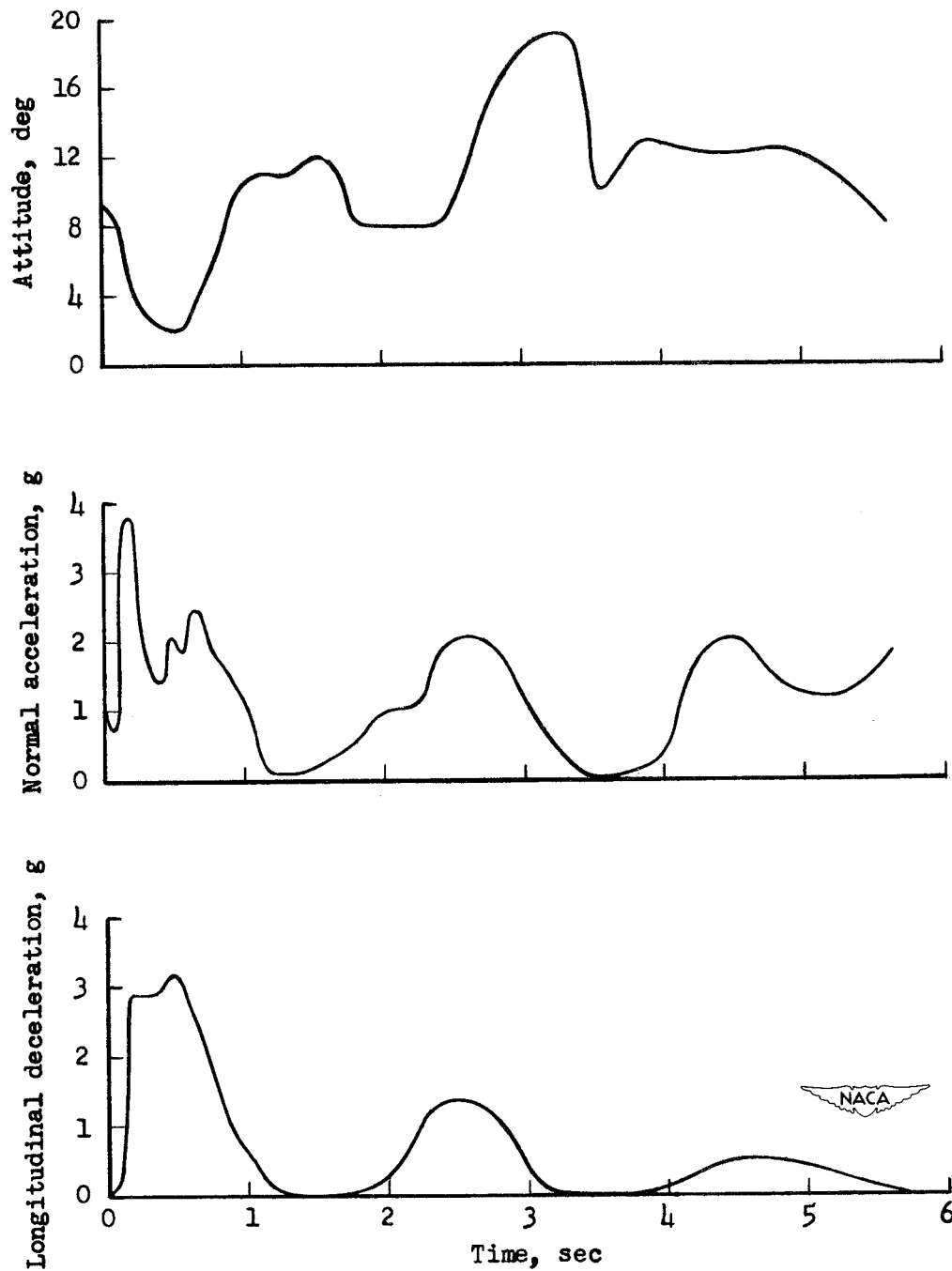
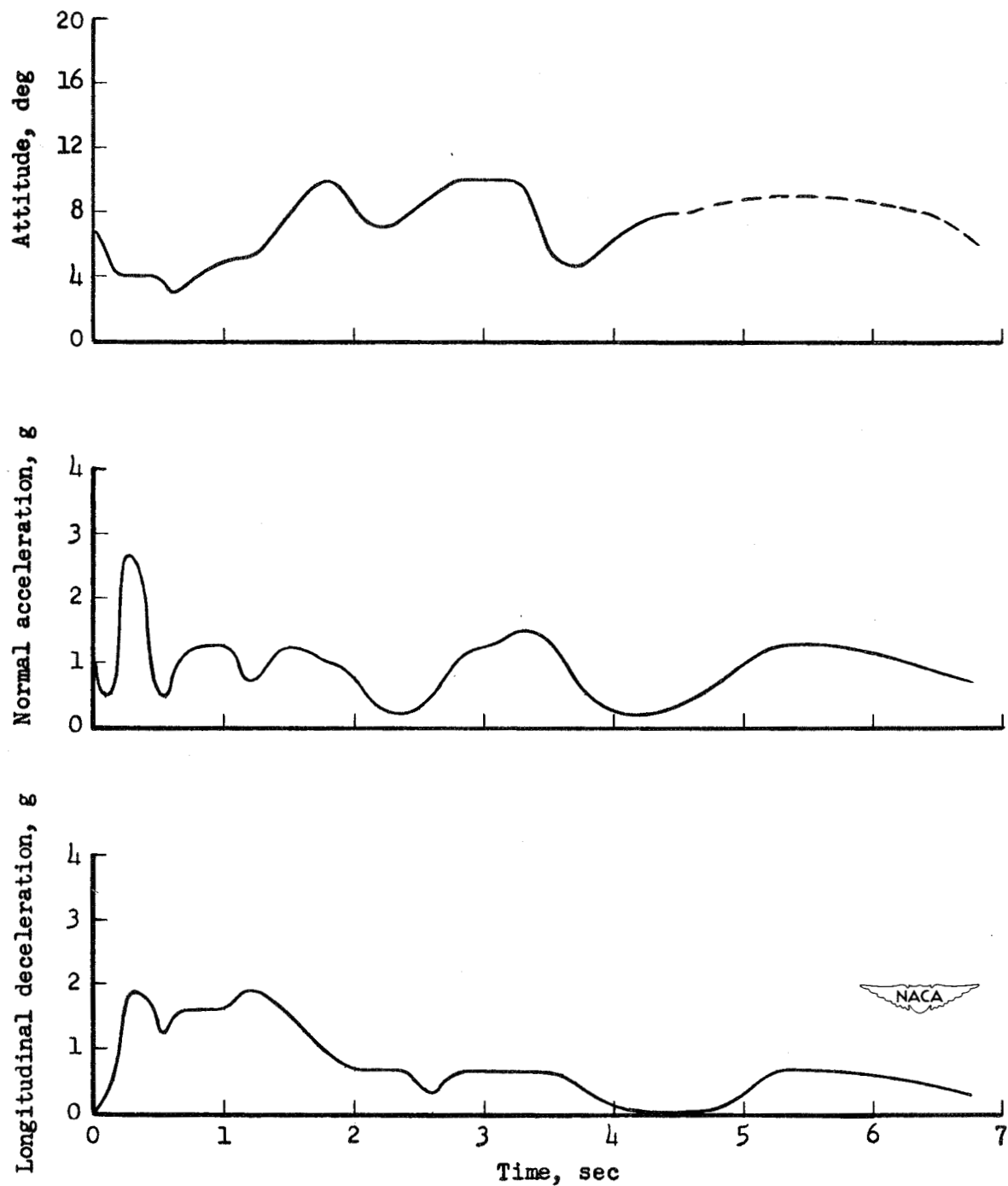


Figure 6.- Model with crumpled rear-fuselage section installed.



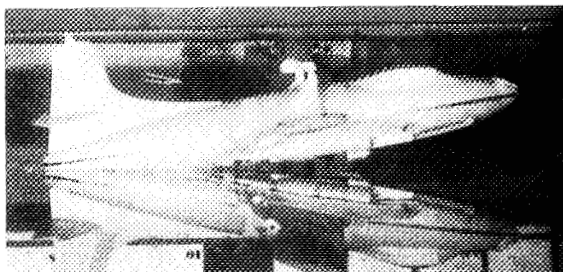
(a) Landing attitude,  $12^\circ$ ; speed, 101 knots.

Figure 7.- Typical time-history curves of longitudinal decelerations, normal accelerations, and attitude. Ditchings were made with the flaps down  $40^\circ$ , nacelle fairings removed, and simulated engines and crumpled rear-fuselage section installed. All values are full scale.

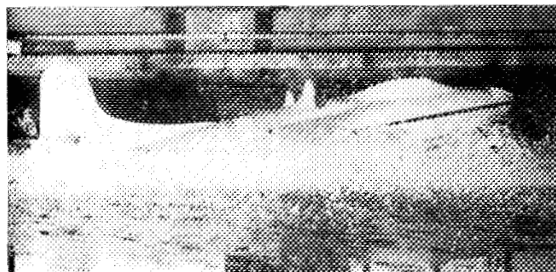


(b) Landing attitude,  $8^{\circ}$ ; speed, 111 knots.

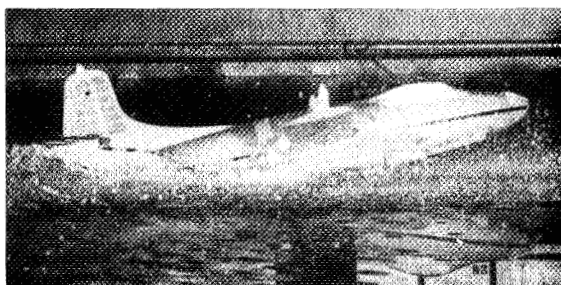
Figure 7.- Concluded.



Near contact



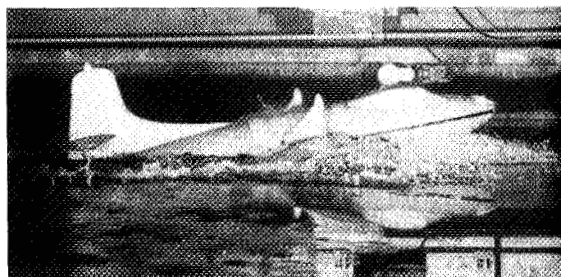
120 feet



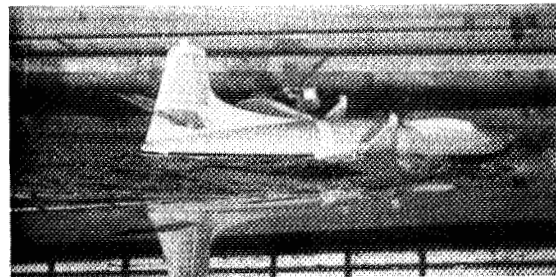
230 feet



310 feet



420 feet



500 feet



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Figure 8.- Sequence photographs of a typical model ditching with nacelle fairings removed, simulated engines and crumpled rear-fuselage section installed. Landing attitude,  $12^\circ$ ; flaps, down  $40^\circ$ ; speed, 101 knots. All values are full scale.

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